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PRELIMINARY STUDY OF THE USE OF INFRARED RADIATION TO REVEAL LUBRICATION BEHAVIOR

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ABSTRACT

The use of infrared radiation to investigate the formation and failure of lubricating films is described. The technique relies on the infrared radiation emitted from the bearing surfaces. Proper interpretation of the intensity distribution which is a function of temperature, emissivity, and interference effects reveals the lubrication behavior.

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SUMMARY

The infrared radiation emitted from a steel ball and a sapphire flat was measured with a scanning infrared microscope. Preliminary results show that the reflection and transmission of the component surfaces give rise to interference fringes which can be used to measure the separation between bearing surfaces. Local surface oxides are shown to influence the intensity distribution due to variation in emissivity. Since the radiation intensity is also a function of temperature, the detection and display of infrared radiation can be useful for observing both the formation and failure of lubricating films.

INTRODUCTION

Infrared radiation emitted from surfaces may be useful for investigating the mechanisms associated with the formation and failure of a lubricant film. The feasibility of this concept became apparent while exploring the capabilities of an infrared microscanner. The usefulness of infrared radiation is that it provides a measuring technique for three basic physical changes associated with film failure; that is, the measurement of film thickness, the detection of surface damage, and the measurement of temperature change which accompanies film failure.

The purpose of this report is to present some preliminary results which illustrate the feasibility and potential of infrared measurements.

FILM THICKNESS

The measurement of film thickness is an important parameter for the understanding of the formation of lubricating films by hydrodynamic or elastohydrodynamic action. Film thickness is also important for understanding the behavior of lubricants under the high pressure, temperature, and shear conditions found in elastohydrodynamic lubrication. Interferometry has successfully been used to measure the thickness of these films which separate the bearing surfaces (refs. 1 to 3). When used with an external source of visible light (0.4 to 0.7 micron wavelength range), interferometry provides a precise measurement in the thin film range, but requires exceptionally smooth surfaces (<1 μin. rms) for good fringe visibility.

The use of longer wavelengths (1.8 to 5.5 μ) in the infrared range causes larger fringe spacing, but allows more commonly textured surfaces to be used (up to approximately 8 μin. rms).

Figure 1 shows the interference fringes formed between the reflecting surfaces of a steel ball and a sapphire flat. The infrared radiation was provided by the thermal energy emitted from the bearing surfaces which were several degrees above room temperature. The intensity distribution was detected and displayed with a Barnes Infrared MicroScanner (RM-50). With a 40X objective, the MicroScanner scans a field of 0.064 by 0.064 inches in 1 second with a spatial resolution of 0.001 inch. A cooled indium antimonide detector measures radiation in the 1.8 to 5.5 micron range. This wide wavelength range causes the fringe contrast to decrease rapidly with path difference. Thus only a few fringes can be seen. Greater fringe visibility (contrast) can be obtained by using spectral limiting filters. The single-line scan shown in figure 1 aids the determination of fringe maxima and minima. This is important for measurement accuracy since fringes in the infrared range are relatively far apart. Figure 2 shows the fringes in a three-dimensional isometric display. It reveals clearly the intensity variation across the field of view.

SURFACE DAMAGE AND TEMPERATURE

In addition to the interference effect, the infrared radiation emitted is sensitive to changes in surface temperature and emissivity. These changes may collectively or individually shed light on some of the problems concerning frictional heating and surface deterioration. If the surface emissivity is known or calibrated, temperature can be obtained from the gray scales and digital radiance readings which are displayed as shown in figure 1. (Surface coatings which reduce reflection can eliminate interference effects.) Moreover, if a uniform temperature distribution is assumed, local surface damage or deposits which change the material emissivity can be detected. This is shown in figure 3 where the local intensity peaks were found to represent oxide formation on the steel ball surface.

CONCLUDING REMARKS

While infrared radiation is often used to measure temperature, suitable detection and display of infrared radiation can also show the effects of interference and emissivity. Proper interpretation of these effects can reveal lubrication behavior in terms of film thickness, heat generation, and surface degradation. These are important features for understanding the mechanisms associated with the formation and failure of a lubricant film.

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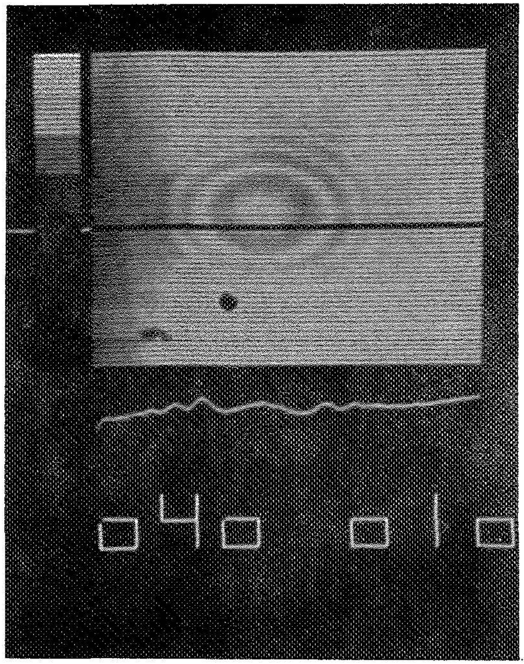

Figure 1. - Detection and display of infrared radiation shows interferences fringes which have formed between a heated steel ball in contact with a sapphire flat. (Dark spots in photo are due to defects in cathode ray tube).

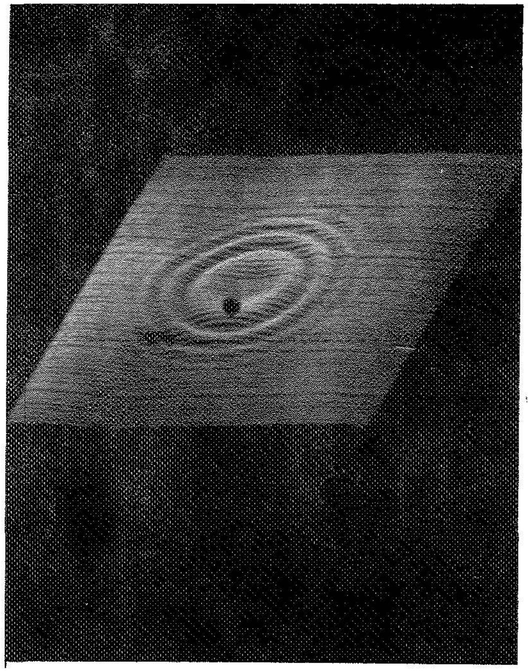

Figure 2. - Three dimensional isometric display shows variation of thermal radiation due to interference effects between a steel ball and a sapphire flat.

Figure 3. - Three dimensional isometric display reveals radiation intensity peaks. These are caused by local oxide deposits which have a higher emissivety than a clean steel surface.